Environment and Natural Resources Trust Fund

2025 Request for Proposal

General Information

Proposal ID: 2025-208

Proposal Title: Sustainable Pilot-Scale Continuous Bin Composter Development

Project Manager Information

Name: Roger Ruan

Organization: U of MN - College of Food, Agricultural and Natural Resource Sciences

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Project Basic Information

Project Summary: Developing a pilot scale continuous composter that integrates leachate recirculation, intelligent airflow control, and heat-to-energy conversion for maximized resource recovery and minimized environmental impacts.

ENRTF Funds Requested: $250,000

Proposed Project Completion: June 30, 2027

LCCMR Funding Category: Small Projects (H)

Secondary Category: Air Quality, Climate Change, and Renewable Energy (E)

Project Location

What is the best scale for describing where your work will take place?

Statewide

What is the best scale to describe the area impacted by your work?

Statewide

When will the work impact occur?

During the Project and In the Future

Narrative

Describe the opportunity or problem your proposal seeks to address. Include any relevant background information.

Composting is a conventional aerobic process for recycling organic waste. Current composting practices rely on the active work of mesophilic and thermophilic bacteria to elevate compost temperatures beyond 70°C, which favors the biological degradation of compost materials and pathogens inactivation. The resulting product, a rich, humus-like substance, serves as a potent soil amendment and fertilizer. While composting is commonly conducted in a small or pilot scale , large-scale operations typically employ batch processes in pile or drum composters, which involve manual loading, posing a significant labor challenge. The imprecise air distribution also results in uneven heating and the production of methane and H2S. Furthermore, the dissipation of generated heat over time reduces energy efficiency, hiders industrialization and profitability. Additionally, traditional pile composting usually lacks insulation and sealing, leading to lower composting temperatures and increased leachate generation, contaminating the groundwater. To enhance composting process's scalability, sustainability, and economic viability, a new configuration and processing method are crucial.

What is your proposed solution to the problem or opportunity discussed above? Introduce us to the work you are seeking funding to do. You will be asked to expand on this proposed solution in Activities & Milestones.

The objective of this project is to develop a large-scale, in-vessel composting unit that addresses the limitations of the current methods. An extrusion screw will be installed inside the composter for continuous loading and discharge, promoting mechanical mixing and pushing the compost material forward. This design ensures an even distribution of airflow, maintaining optimal conditions for mesophilic and thermophilic bacterial activity and preventing the formation of anaerobic regions that produce H2S or methane.

Efficient leachate management is achieved by collecting and recirculating it to maintain uniform compost material moisture levels. To mitigate NH3 emissions, biofilters composed of woody materials and biochar will be connected to the air outlet. To achieve the highest level of heat conservation, the composter will be insulated externally, and a heat pump or thermoelectric generator will be integrated to collect the heat for external uses such as in-house heating and electricity generation. Additionally, components such as electric fields and external heating devices can be added to the composter to enhance efficiency.

This innovative configuration ensures continuous, large-scale composting with maximum energy use efficiency and minimal environmental impact, making it a transformative solution for the waste management and agricultural sectors.

What are the specific project outcomes as they relate to the public purpose of protection, conservation, preservation, and enhancement of the state's natural resources?

The proposed technology offers a new configuration designed for industrial composting to effectively manage large volumes of biowaste. This continuous process streamlines operations and reduces labor requirements. By implementing regulated airflow, leachate recirculation, and air filtration, this closed system minimizes environmental impact to only CO2 emissions. The incorporation of a heat pump optimizes energy utilization from compost materials, further enhancing efficiency. The final products are heat and high-quality composts. Overall, this innovative technology not only improves energy conservation from biowastes but also reduces their environmental impacts, marking a significant step towards sustainable waste management practices.

Activities and Milestones

Activity 1: Developing and testing the pilot scale composter prototype

Activity Budget: $110,000

Activity Description:
The activity will focus on constructing and testing a 200L in-vessel composter prototype equipped with such components as composting cylinder, feeding inlet, extrusion screw, air distribution and recirculation pipeline, leachate recirculation pipelines, sensing components, and the discharge outlet. Wastes such as food waste, manure, yard waste and municipal waste are initially loaded into the composter for preliminary degradation. Following preliminary degradation, the extrusion screw will slowly convey the compost material forward to the discharge side. Upon reaching the end of the preliminary vessel, the material will enter the secondary vessel, facilitating the reshaping of the compost structure in preparation for the subsequent heating cycle. During the process, internal temperature and oxygen concentration will be monitored by sensors installed inside the compost vessel. Air will be distributed throughout different locations of compost materials to ensure sufficient supply. Leachate will be recirculated to the top of the compost material to maintain the overall moisture.

Activity Milestones:

Description	Approximate Completion Date
Build the 200 L composter with the extrusion screw	November 30, 2025
Add the air and leachate sensors and recirculation equipment	January 31, 2026

Activity 2: Expanding the prototype with extension equipment

Activity Budget: $80,000

Activity Description:
Elements such as heat pump and air filtration equipment will be added to the base prototype. Heat pump allows the collection and transfer of the heat from composting process to another medium. The utilization of heat will increase the energy efficiency of the process. Air filtration units can include wood materials and biochar. They can retain the ammonia from emitting to the atmosphere. There is alternative equipment that can be added to the composter. For example, the external heating layer can increase the compost material temperature to inactivate pathogens if animal mortalities are to be composted during an outbreak (Akdeniz, 2019; Wang et al., 2021). A weak electrical field can be added to facilitate the degradation and further reduce the GHG emission (Shen et al., 2024; Tang et al., 2019).

Activity Milestones:

Description	Approximate Completion Date
Add heat pump and air filtration units	March 31, 2026
Perform a continuous composting test	July 31, 2026
Add additional equipment such as external heating layer and electrodes inside the composter	September 30, 2026
Perform two continuous composting tests with external heating layer and electrical field, respectively	January 31, 2027

Activity 3: Benchmarking with Techno-Economic Analysis and Life Cycle Assessment

Activity Budget: $60,000

Activity Description:
We will benchmark the performance of this pilot-scale composter against conventional composting, combustion, and

anaerobic digestion processes. This evaluation will include comprehensive techno-economic and life cycle assessment analyses to evaluate the economic viability and environmental impacts of the proposed technology. The analyses will be conducted using a model that simulates various operational conditions, such as the physicochemical characteristics of raw materials, ambient temperature, loading amount, and retention time. The unique features of the extended equipment in this technology will result in a distinct system boundary, which is anticipated to have a more positive impact on the environment and be more feasible for large-scale manufacturing. All treatment alternatives will be evaluated systematically to provide comprehensive insights into the trade-offs between economic benefits and potential environmental impacts when scaling up the technology for commercial use.

Activity Milestones:

Description	Approximate Completion Date
Techno-economic analysis result	June 30, 2027
Life Cycle Assessment result	June 30, 2027

Long-Term Implementation and Funding

Describe how the results will be implemented and how any ongoing effort will be funded. If not already addressed as part of the project, how will findings, results, and products developed be implemented after project completion? If additional work is needed, how will this work be funded?

The experiment will initially be conducted at the pilot scale and then extended to large-scale industrial production in the future. To facilitate the scale-up for larger operations, we intend to seek additional investment. This investment may be sourced from industry partners as well as private, state, and federal funding avenues. We will also seek a test site for the large-scale operation. A successful demonstration will promote the commercialization of this technology for a sustainable and more effective future of composting.

Other ENRTF Appropriations Awarded in the Last Six Years

Name	Appropriation	Amount Awarded
Methods to Destroy PFAS in Landfill Leachates	M.L. 2022, , Chp. 94, Art. , Sec. 2, Subd. 04a	$200,000

Project Manager and Organization Qualifications

Project Manager Name: Roger Ruan

Job Title: Professor and Director

Provide description of the project manager's qualifications to manage the proposed project.

Dr. Roger Ruan is a Fellow of the National Academy of Inventors, the American Society of Agricultural and Biological Engineers, the Institute of Food Technologists, the International Association of Advanced Materials, and Vebleo, and have received many other awards, including International Bioprocessing Association's Pandey Award, CAFS Professional Achievement, Scientist of IAAM, etc. Dr. Ruan's research areas include renewable energy and environment technologies for sustainable development and circular economy. His research has focused on biomass and solid wastes such as plastic wastes pyrolysis and gasification for chemicals, materials, fuels, and energy production; wastewater treatment and utilization through novel anaerobic digestion, microalgae cultivation; airborne and other pathogen disinfection and pollutant control; innovative catalytic non-thermal plasma, low temperature microwave and pulse microwave, photocatalytic intensive pulse light, and NMR/MRI technologies development and applications in nitrogen fixation, food safety assurance, and food quality improvement; and food engineering and various value-added processing. Dr. Ruan has published over 600 papers in refereed journals, two books, and 28 book chapters, and holds 19 US patents. He is also a top-cited author in engineering and technologies, with an h-index of 96, i10-index of 480, and over 37,000 citations. He has received over 200 projects totaling over $45 million in various funding for research, including major funding from USDA, DOE, DOT, DOD, LCCMR, and industries. He was the project manager of several earlier LCCMR funded projects which resulted in the issuance of US patents and licensing of technologies. He has the technical expertise and project management experience to ensure the execution of proposed project.

Organization: U of MN - College of Food, Agricultural and Natural Resource Sciences

Organization Description:

The Center for Biorefining is a University of Minnesota research center and help coordinate University efforts and resources to conduct exploratory fundamental and applied research; provide education on bioenergy, biochemicals and biomaterials; stimulate collaboration among the University researchers, other public sector investigators, and private investigators in biobased production technology development; promote technology transfer to industries; and foster economic development in rural areas. The Center's research programs have been founded by DOE, USDA, DOT, DOD, LCCMR, IREE, Xcel Energy, and other federal and state agencies, NGOs, and private companies. The Center is equipped

with state of the arts analytical instruments, and processing facilities ranging from bench to pilot scale.

The Department of Bioproducts and Biosystems Engineering, in CFANS, discovers and teaches solutions for the sustainable use of renewable resources and the enhancement of the environment. We discover innovative solutions to address challenges in the sustainable production and consumption of food, feed, fiber, materials, and chemicals by integrating engineering, science, technology, and management into all degree programs.

https://bbe.umn.edu/biobrief

Budget Summary

Category / Name	Subcategory or Type	Description	Purpose	Gen. Ineligible	% Benefits	# FTE	Classified Staff?	$ Amount
Personnel								
Professor/Faculty		PI - summer salary			37.1%	0.1		$27,831
Professional Researcher		Manage lab, develop methodology, conduct research and analysis			37.1%	1		$83,494
Post doctoral researcher		research			27.1%	1.5		$129,007
							Sub Total	**$240,332**
Contracts and Services								
							Sub Total	**-**
Equipment, Tools, and Supplies								
	Tools and Supplies	Purchase of lab and miscellaneous supplies, including materials to build composting system, chemicals reagents, consumable supplies for analytical instruments, PPEs, etc.	For running experiments and operating the systems.					$9,668
							Sub Total	**$9,668**
Capital Expenditures								
							Sub Total	**-**
Acquisitions and Stewardship								
							Sub Total	**-**
Travel In Minnesota								
							Sub Total	**-**
Travel Outside Minnesota								
							Sub Total	**-**

Printing and Publication								
							Sub Total	**-**
Other Expenses								
							Sub Total	**-**
							Grand Total	**$250,000**

Classified Staff or Generally Ineligible Expenses

Category/Name	Subcategory or Type	Description	Justification Ineligible Expense or Classified Staff Request

Non ENRTF Funds

Category	Specific Source	Use	Status	Amount
State				
			State Sub Total	**-**
Non-State				
			Non State Sub Total	**-**
			Funds Total	**-**

Total Project Cost: $250,000

This amount accurately reflects total project cost?

Yes

Attachments

Required Attachments

Visual Component

File: 327749cb-793.pdf

Alternate Text for Visual Component

The visual abstract shows the proposed composting unit for pilot or large-scale continuous operations. Biowastes are fed into the composter as an energy source. The only outlet gas will be CO2. Products recovered are mature compost and heat....

Supplemental Attachments

Capital Project Questionnaire, Budget Supplements, Support Letter, Photos, Media, Other

Title	File
SPA Cover Letter - Composter	509a5020-f10.pdf

Administrative Use

Does your project include restoration or acquisition of land rights?

No

Does your project have potential for royalties, copyrights, patents, sale of products and assets, or revenue generation?

No

Do you understand and acknowledge IP and revenue-return and sharing requirements in 116P.10?

N/A

Do you wish to request reinvestment of any revenues into your project instead of returning revenue to the ENRTF?

N/A

Does your project include original, hypothesis-driven research?

Yes

Does the organization have a fiscal agent for this project?

No

Does your project include the pre-design, design, construction, or renovation of a building, trail, campground, or other fixed capital asset costing $10,000 or more or large-scale stream or wetland restoration?

No

Do you propose using an appropriation from the Environment and Natural Resources Trust Fund to conduct a project that provides children's services (as defined in Minnesota Statutes section 299C.61 Subd.7 as "the provision of care, treatment, education, training, instruction, or recreation to children")?

No

Provide the name(s) and organization(s) of additional individuals assisting in the completion of this proposal:

Paul Chen, Juer Liu, Wendy Moylan, University of Minnesota